Core-Collapse Supernovae

Scientific and Computational Challenges

Use core-collapse supernova simulations as probes of key neutrino properties, the properties of dense matter, and the origin of the elements.

Perform 3D, multi-physics simulations of core-collapse supernovae.

Summary of Research Direction

Develop a quantum kinetic theory of neutrinos in core-collapse supernovae and computational approaches to the resultant equations on exascale platforms.

Develop multi-core-aware algorithms to incorporate all requisite physics.

Potential Scientific Impact

A quantitative, predictive model of core-collapse supernovae allowing us to predict a host of observables.

Scalable computational approaches to 3D, conservative, multi-angle, multi-frequency radiation magnetohydrodynamics.

Potential impact on Nuclear Physics

Core-collapse supernova simulations with adequate physical fidelity can be used to constrain properties of dense and neutron-rich matter.

Thermonuclear Supernovae

Scientific and Computational Challenges

Use thermonuclear supernova simulations to understand nuclear burning in strong gravity and to calibrate Type Ia standard candles, allowing a quantitative study of dark energy.

Perform 3D, highly-resolved simulations of thermonuclear supernovae.

Summary of Research Direction

Develop a suite of codes able to span the disparate spatial scales of the problem, from the scale of the white dwarf to the flame width, incorporating all requisite physics.

Integrate these implementations into simulations modeling the entire event, including detailed nuclear kinetics and weak interaction physics.

Potential Scientific Impact

A calibrated Type Ia distance scale, including potential environmental effects (e.g. metallicity).

Detailed knowledge of the explosion mechanism and the nucleosynthetic consequences.

Develop codes for reactive turbulent flow capable of strong scaling to >10^5 cores.

Potential impact on Nuclear Physics

Understanding of weak interaction physics at high neutron excess.

Connections to spectroscopic observations can constrain reaction rates, partition functions, etc. through element synthesis.

- 3 years: Whole-star simulations with resolutions of ~1km.
- 6 years: Whole-star simulations with reduced nuclear kinetics and resolutions approaching the Gibson length scale.
- 10 years: Whole-star simulations capturing all DDT-crucial scales with detailed nuclear kinetics.